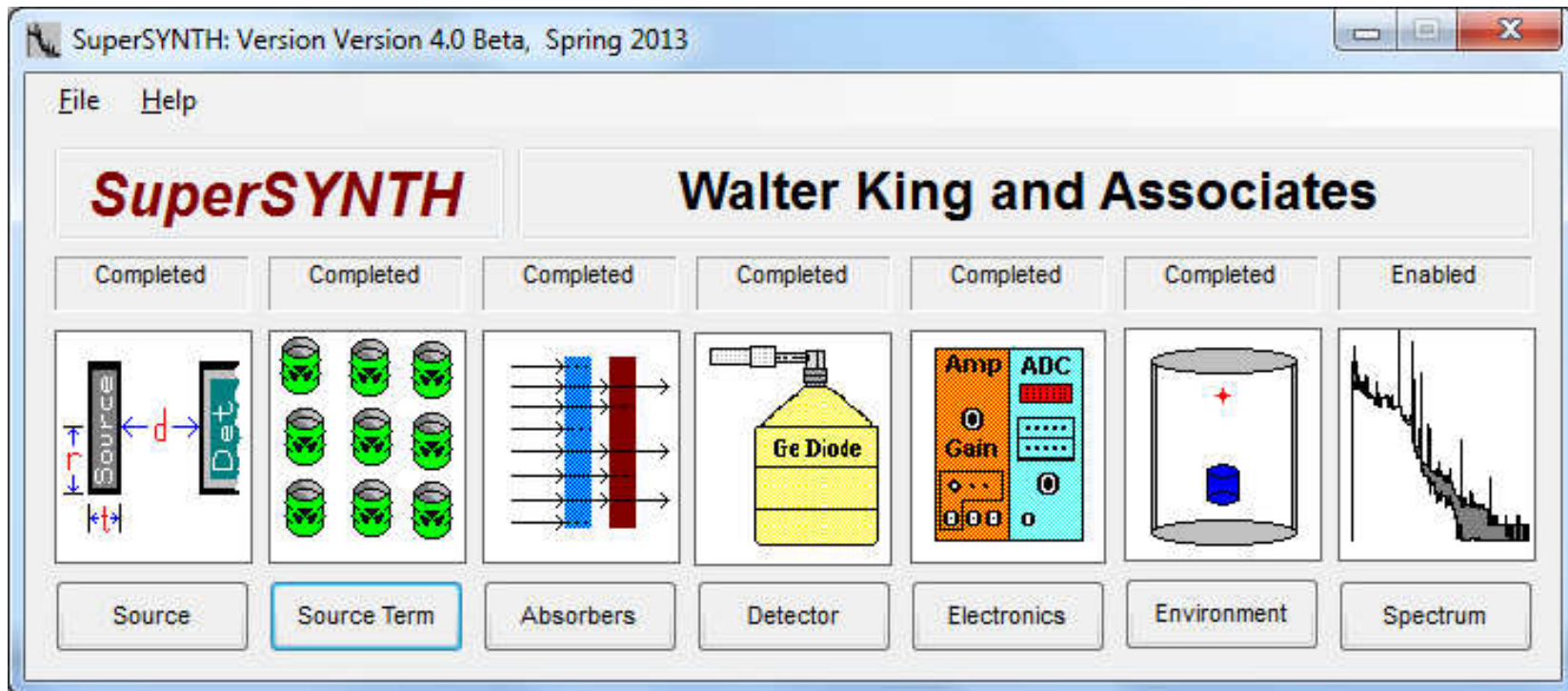


# SuperSYNTH

## A Gamma-Ray Spectroscopy Interface to MCNP

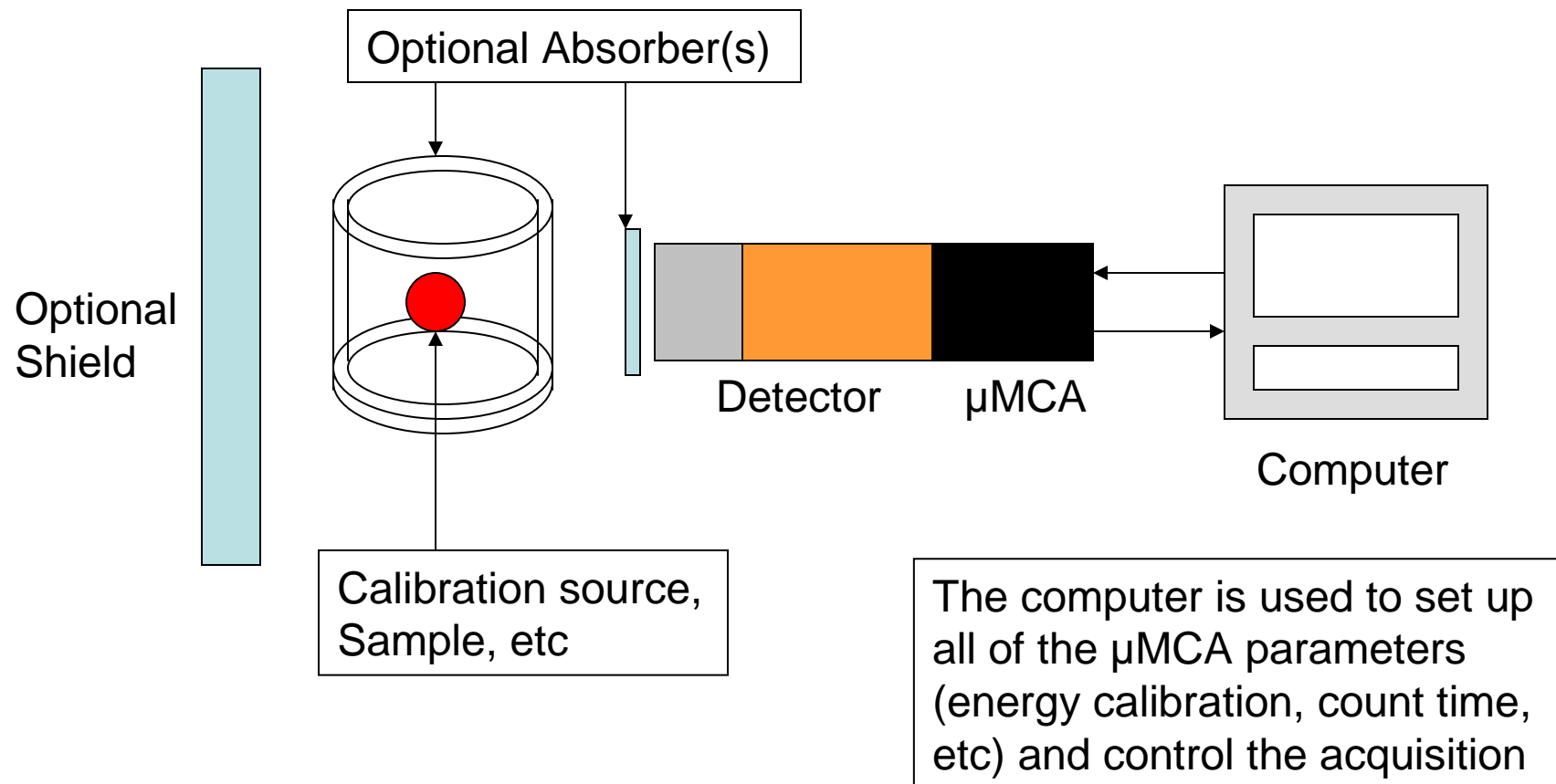


# Overview

## What SuperSYNTH is and does

- A Gamma-Ray Spectroscopy Interface to MCNP designed to simplify modeling of laboratory and real world measurements
- Requires MCNP to be installed and functioning to generate spectra (doesn't need MCNP if only generating an input deck)
- Organizes the problem into six logical steps
- Generates a fully commented and functional MCNP input deck
- Runs MCNP, then parses the generated mctal file to produce a spectrum that can be viewed and saved in a number of different spectral data formats

# An Over Simplified Gamma-Ray Measurement



# Six Easy Pieces

(With apologies to Richard Feynman)

- Source Geometry and Bulk Composition
- Source Term ( $^{241}\text{Am}$ ,  $^{137}\text{Cs}$ ,  $^{60}\text{Co}$ , etc)
- Absorbers (shape, location, composition, etc)
- Sensor (type, size, resolution, etc)
- Counting Parameters (energy calibration, etc)
- Counting Environment (shield)

=> MCNP => Generated Gamma-Ray Spectrum

# Source Geometry and Composition

SourceGeometry

File Edit Auto Calc Warnings

Source Geometry

Style: Shell

Distance: -2.8 cm

Off Axis: 0.01 cm

☐ Rotate Disk

Mass: 5647.108 g

Radius: 15 cm

Thickness: 0.1 cm

Composition

Material: WGPu DOE 3013

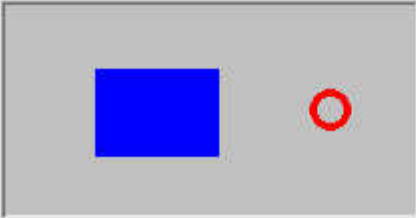
Density: 19.84 g/cm<sup>3</sup>

Element	A	Atom
<span></span>	<span>0</span>	<span>1</span>

Add Element Delete Element

94 239 1 \$ Plutonium

Cancel Return



# Source Geometry

	Mass	Off-Axis	Edge-On
• Point		x	
• Sphere	x	x	
• Shell	x	x	
• Disk	x	x	x

# Source Term

The 'Source Terms' window displays the following configuration and data:

**Input Fields:**

- Element:** Actinium
- Isotope:** 227
- Quantity:** 1 Bq (d/s)
- Decay Time:** 1 s

**Buttons:** Periodic Table, Add to List, Remove from List, Process, Daughters (checkbox), and a calculator icon.

**Table of Source Terms:**

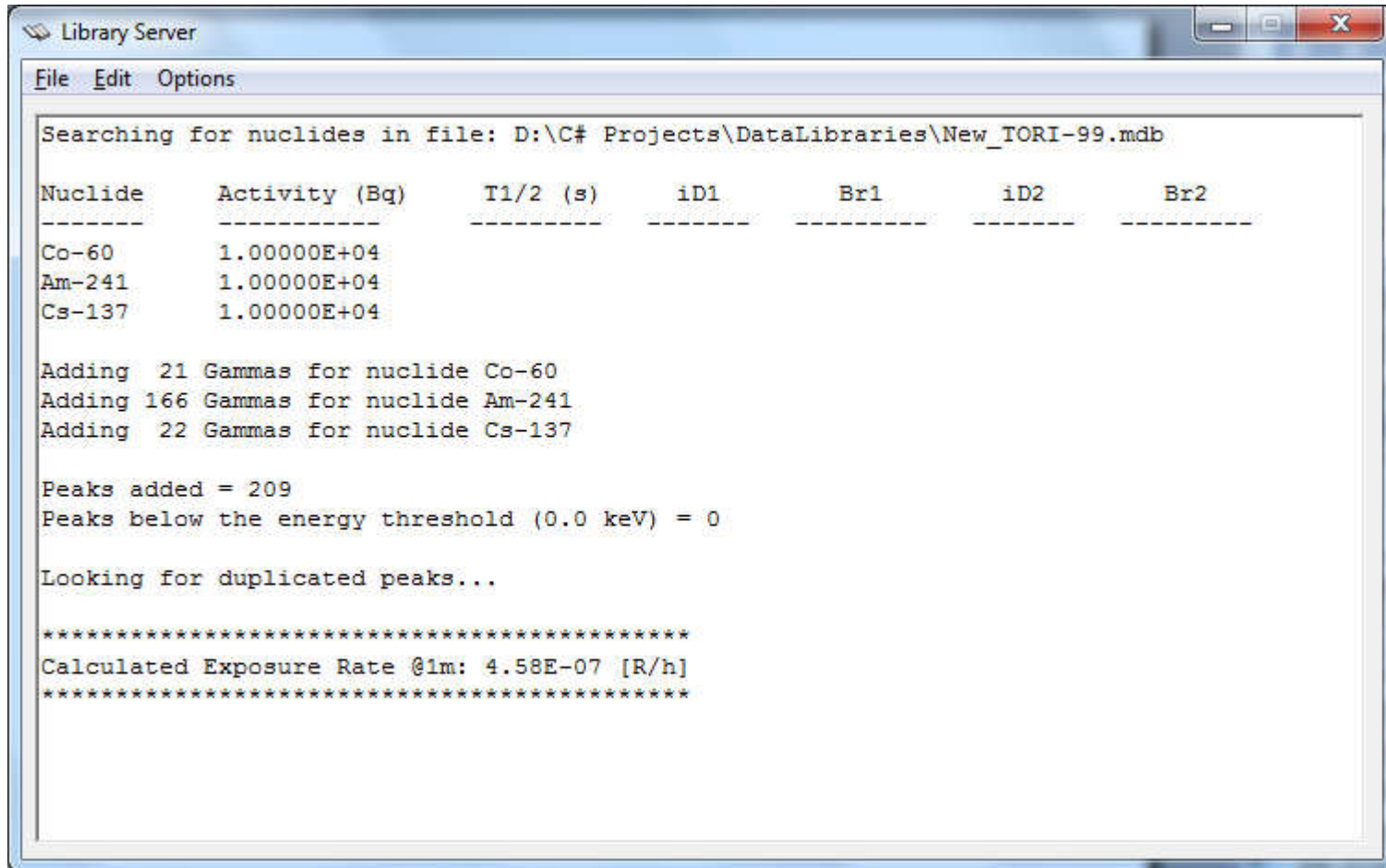
1.00E+04d	270060	False	1s	60 Cobalt
1.00E+04d	950241	False	1s	241 Americium
1.00E+04d	550137	False	1s	137 Cesium

**Footer:** Library = D:\C# Projects\DataLibraries\New\_TORI-99.mdb

# Gamma-Ray Data Libraries

- Enhanced TORI-99 (based on the LBL Table of Radioactive Isotopes compilation revised to 1999)
- PC\_NuDat (based on the NNDC compilation revised to 2004)
- User Supplied (It's an open format that can implemented as a Microsoft Access or SQLite database)

# Library Server



Library Server

File Edit Options

Searching for nuclides in file: D:\C# Projects\DataLibraries\New\_TORI-99.mdb

Nuclide	Activity (Bq)	T1/2 (s)	iD1	Br1	iD2	Br2
Co-60	1.00000E+04					
Am-241	1.00000E+04					
Cs-137	1.00000E+04					

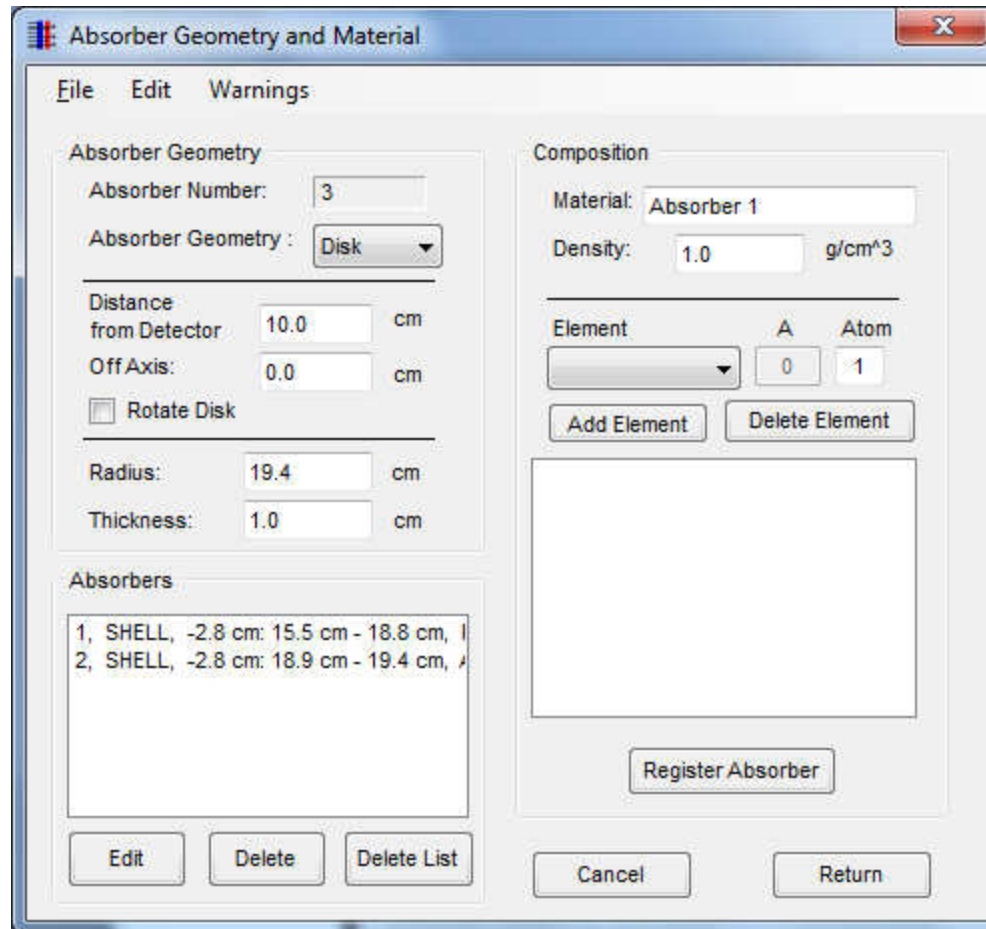
Adding 21 Gammas for nuclide Co-60  
Adding 166 Gammas for nuclide Am-241  
Adding 22 Gammas for nuclide Cs-137

Peaks added = 209  
Peaks below the energy threshold (0.0 keV) = 0

Looking for duplicated peaks...

\*\*\*\*\*  
Calculated Exposure Rate @1m: 4.58E-07 [R/h]  
\*\*\*\*\*

# Absorbers



The image shows a software dialog box titled "Absorber Geometry and Material". It has a menu bar with "File", "Edit", and "Warnings". The dialog is divided into several sections:

- Absorber Geometry:** Contains fields for "Absorber Number" (set to 3), "Absorber Geometry" (set to "Disk"), "Distance from Detector" (10.0 cm), "Off Axis" (0.0 cm), a "Rotate Disk" checkbox, "Radius" (19.4 cm), and "Thickness" (1.0 cm).
- Composition:** Contains a "Material" field (set to "Absorber 1"), a "Density" field (1.0 g/cm<sup>3</sup>), a table for elements, and buttons for "Add Element" and "Delete Element".

Element	A	Atom
	0	1
- Absorbers:** A list box containing two entries:
  - 1, SHELL, -2.8 cm: 15.5 cm - 18.8 cm, I
  - 2, SHELL, -2.8 cm: 18.9 cm - 19.4 cm, A

At the bottom, there are buttons for "Edit", "Delete", "Delete List", "Cancel", "Return", and a "Register Absorber" button located below the Composition section.

# Absorber Geometries

Off-Axis

Edge-On

- Shell

x

- Disk

x

x

# Sensors

- Detailed High Purity Coaxial Ge (Gec)
- Generic Right Circular Cylinder (RCC)
- Generic Box (planar Ge, Large PVT, etc)
- The RCC and Box sensors may be any reasonable size and composition ( there are a number of standard default compositions + user defined materials {Tomato Soup?} )

# Sensors

- Ge sensors have many adjustable parameters in addition to the crystal dimensions
- All three sensor types have a list of standard EndCap and Window materials and allow a “User Defined” material for either of these components

# Germanium Diode

**Frm\_GeCoax**

File Edit FWHM Description

Detector ☒ Gec ☐ RCC ☐ Box

Detector Materials and Geometry

Diode "Type":

Diameter:  cm

Length:  cm

Bulletized: ☒

Dead Layer... Face:  cm

Walls:  cm

Hole Diameter:  cm

Hole Offset:  cm

EndCap:

EndCap Thickness:  cm

Window:

Window Thickness:  cm

EndCap Spacing:  cm

Composition

☐ End Cap ☒ EndCapWindow

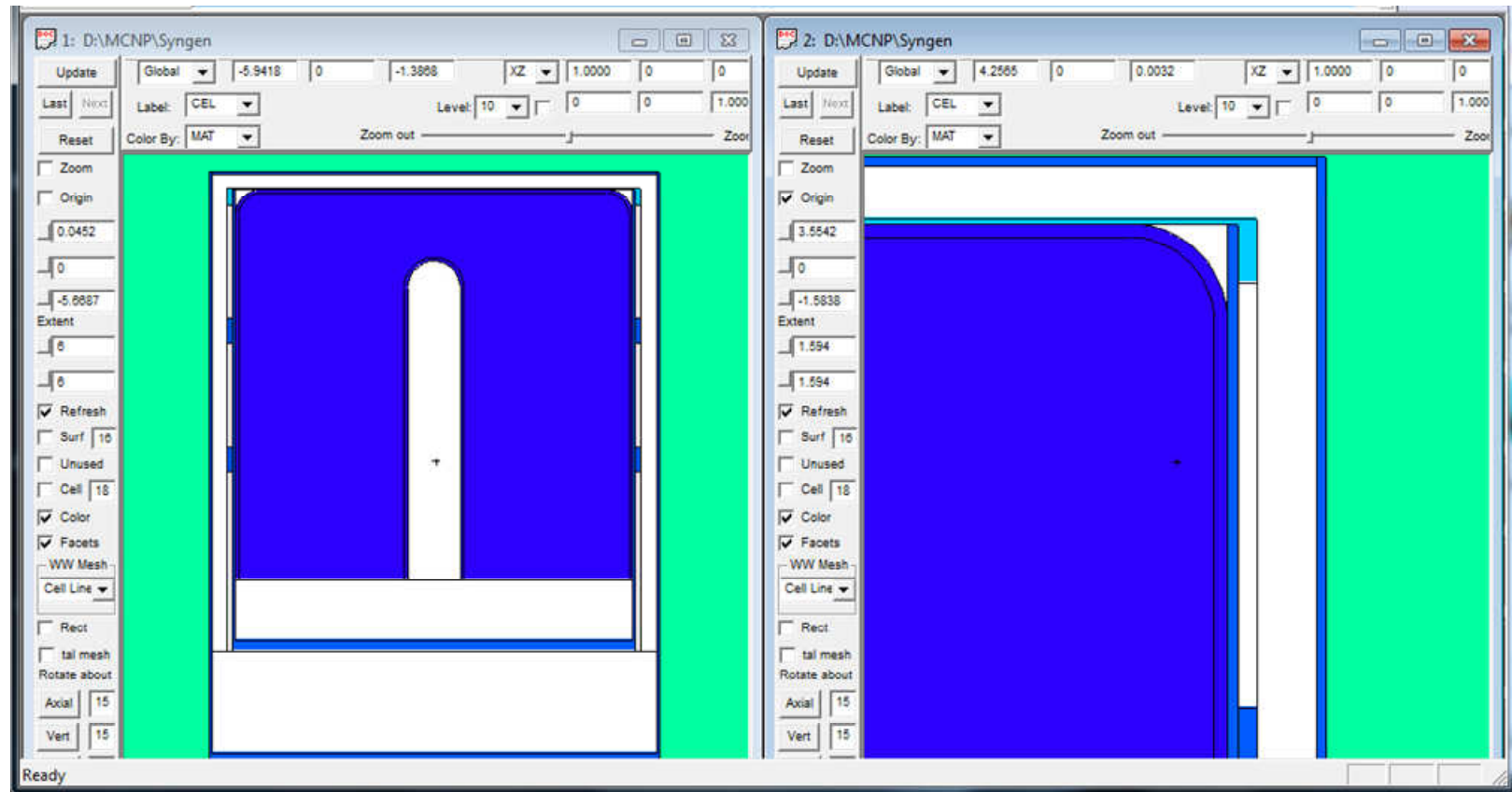
Material:

Density:  g/cm<sup>3</sup>

Element	A	Atom
<input type="text" value=""/>	<input type="text" value="0"/>	<input type="text" value="1"/>

6 0 1 \$ Carbon

# Germanium Diode Model



# RCC Sensor

The screenshot shows a software window titled "Frm\_RCCDetector" with a menu bar (File, Edit, FWHM, Description) and a close button. The window is divided into two main sections: "Detector Materials and Geometry" on the left and "Composition" on the right.

**Detector Materials and Geometry:**

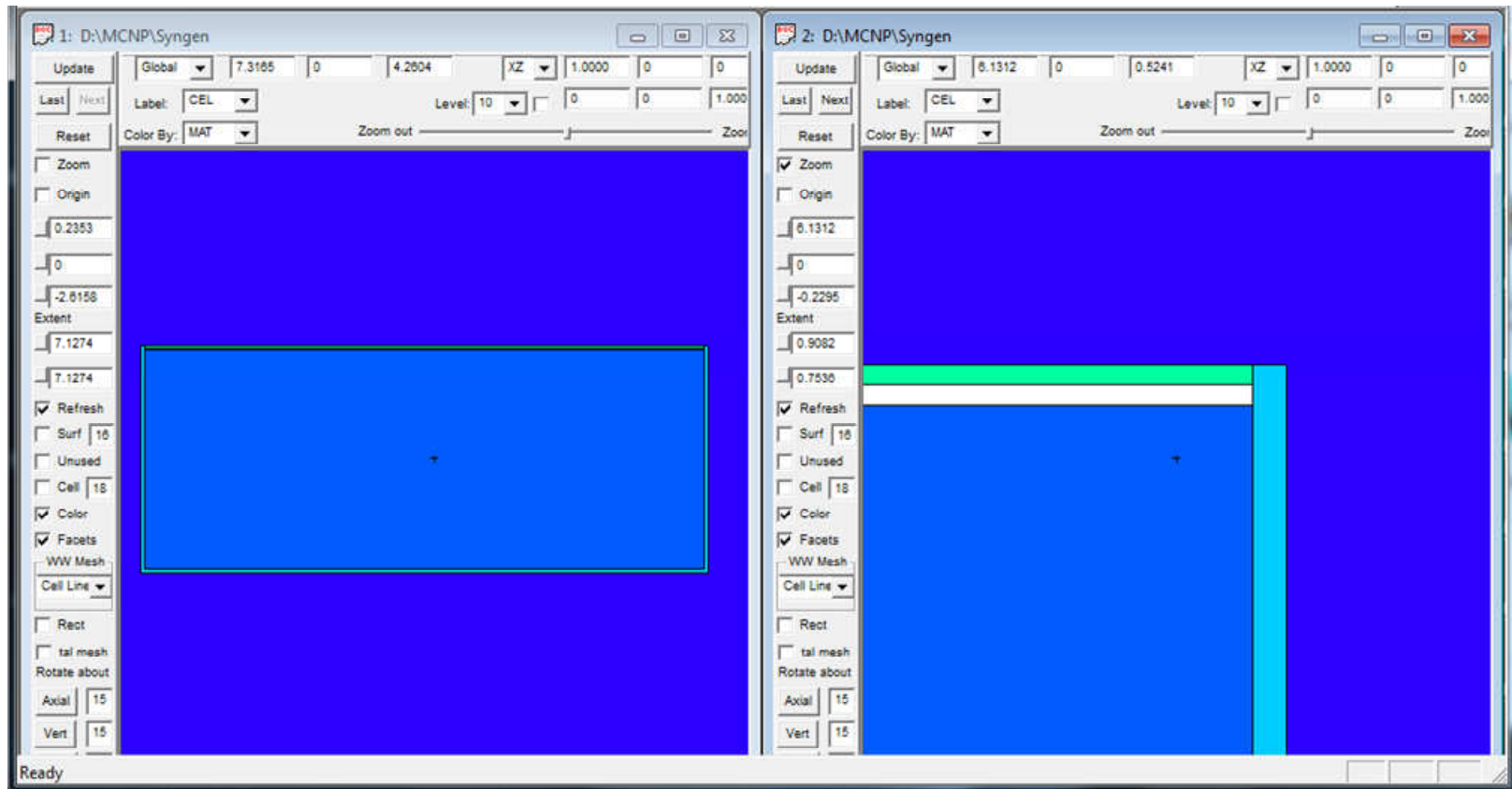
- Detector:** Radio buttons for Gec, **RCC** (selected), and Box.
- Sensor:** A dropdown menu set to "User Defined".
- Diameter:** 12.70 cm
- Length:** 5.08 cm
- Dead Layer Thickness:** 0.000 cm
- EndCap:** A dropdown menu set to "Al".
- EndCap Thickness:** 0.10 cm
- Window:** A dropdown menu set to "Al".
- Window Thickness:** 0.05 cm
- EndCap Spacing:** 0.05 cm

**Composition:**

- Radio buttons for **Detector** (selected), End Cap, and EndCapWindow.
- Material:** Text field containing "Tomato Soup".
- Density:** 0.987 g/cm<sup>3</sup>
- Element:** A dropdown menu.
- A:** 0
- Atom:** 1
- Add Element** and **Delete Element** buttons.
- Material List:** A text area containing:  
1 0 31 \$ Hydrogen  
6 0 19 \$ Carbon  
8 0 11 \$ Oxygen
- Register Material** button.

At the bottom are **Cancel** and **Return** buttons.

# RCC Sensor Model



# Box Sensor

Box Detector

File Edit FWHM Description

Detector ☐ Gec ☐ RCC ☒ Box

Detector Materials and Geometry

Sensor:

Width:  cm

Length:  cm

Depth:  cm

Dead Layer Thickness:  cm

EndCap:

EndCap Thickness:  cm

Window:

Window Thickness:  cm

EndCap Spacing  cm

Composition

☐ Detector ☐ End Cap ☒ EndCapWindow

Material:

Density:  g/cm<sup>3</sup>

Element	A	Atom
<input type="text"/>	<input type="text" value="0"/>	<input type="text" value="1"/>

6 0 1 \$ Carbon

# Tools to make life a bit easier

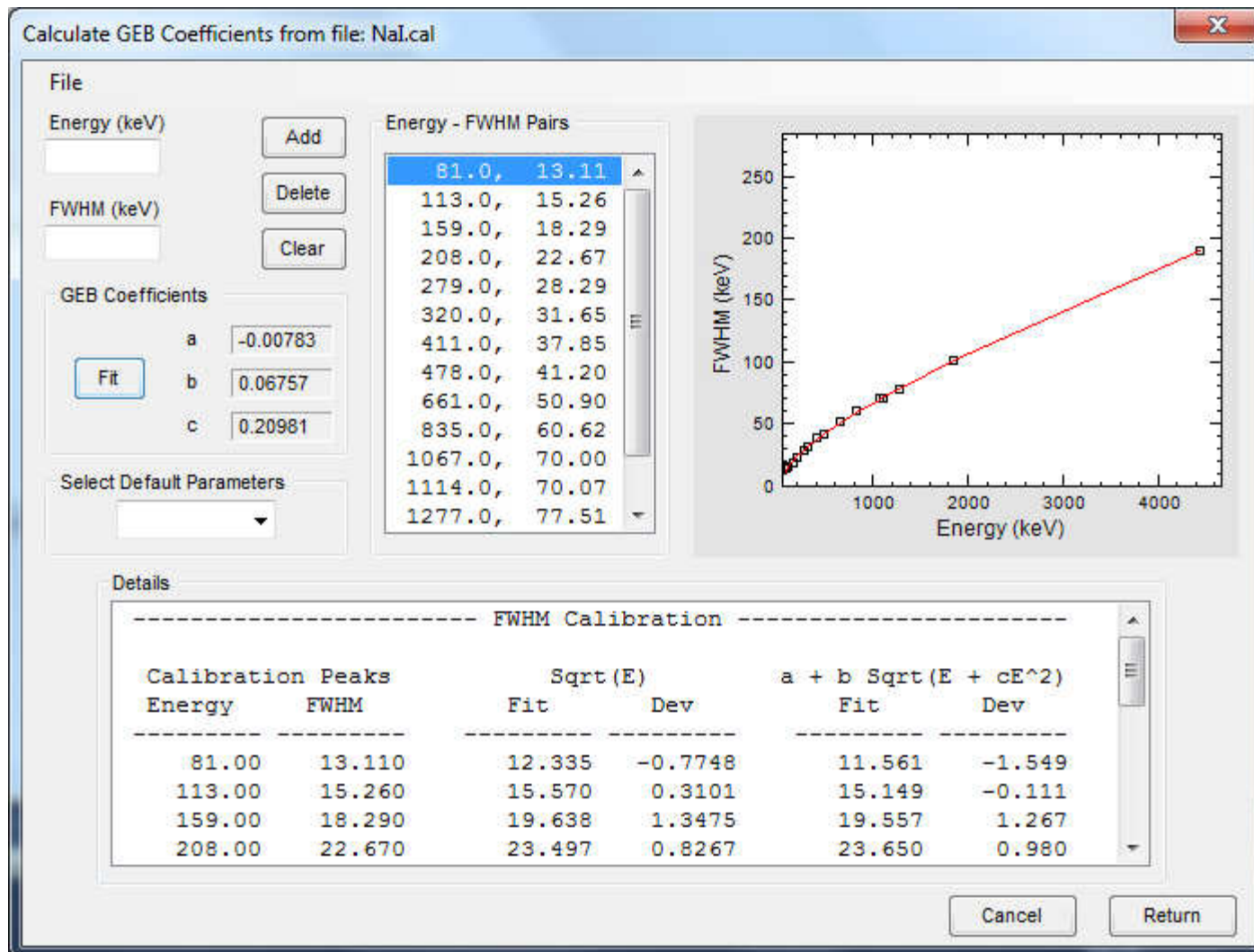
- GEB coefficient calculator to fit the MCNP Full Width at Half Maximum function

$$\text{FWHM} = a + b \cdot \sqrt{E + cE^2}$$

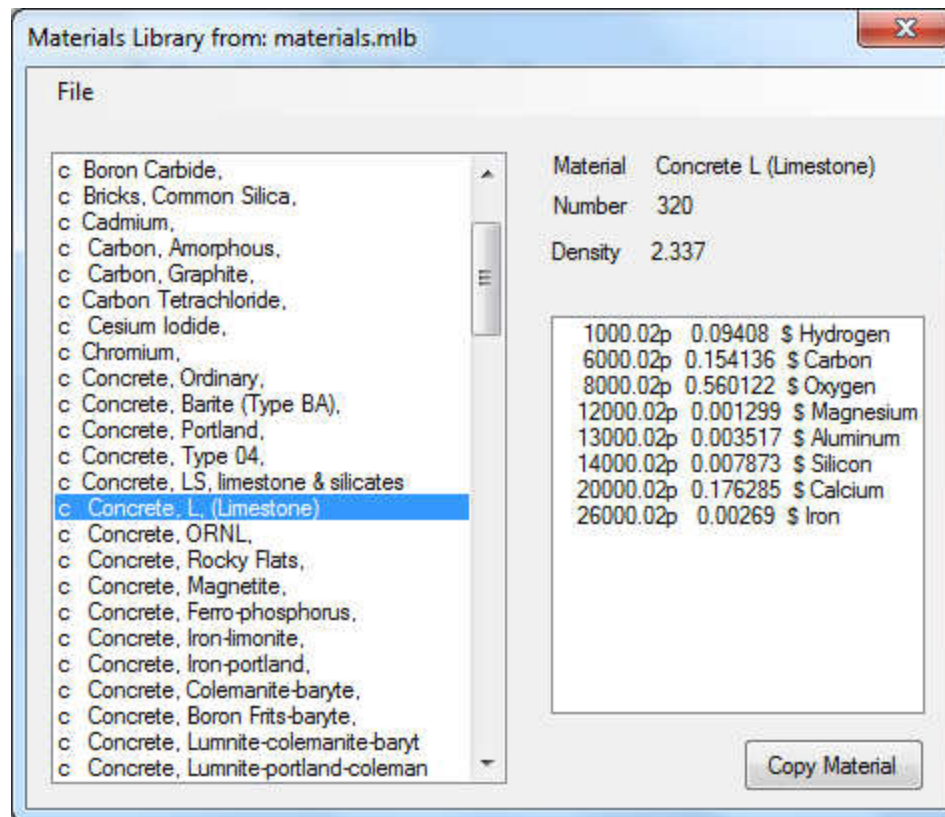
to experimental data

- A Materials Library utility

# GEB Coefficient Calculator



# Materials Library Utility



# Counting Parameters

Counting Parameters

File

Energy Calibration

Zero =  (keV)

Gain =  (keV / ch)

Quad =  (keV / ch<sup>2</sup>)

☐ Nal Intrinsic Non-Linearity

ADC

Channels =

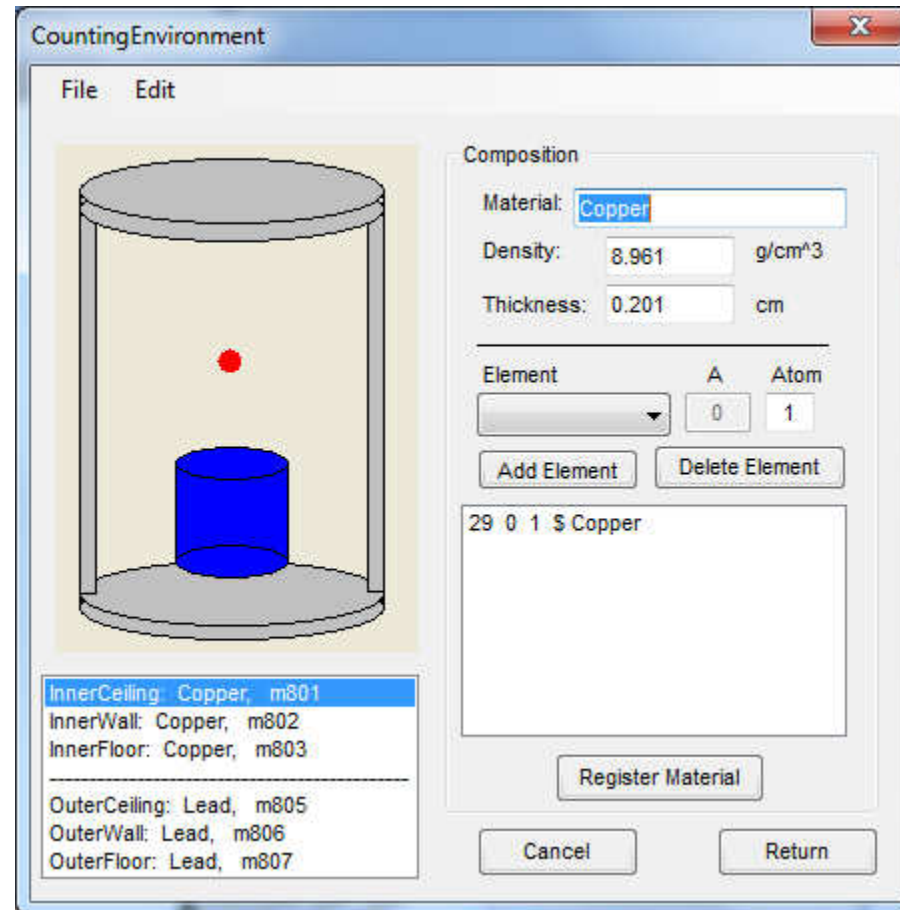
Live Time =  sec.

Full Scale Energy

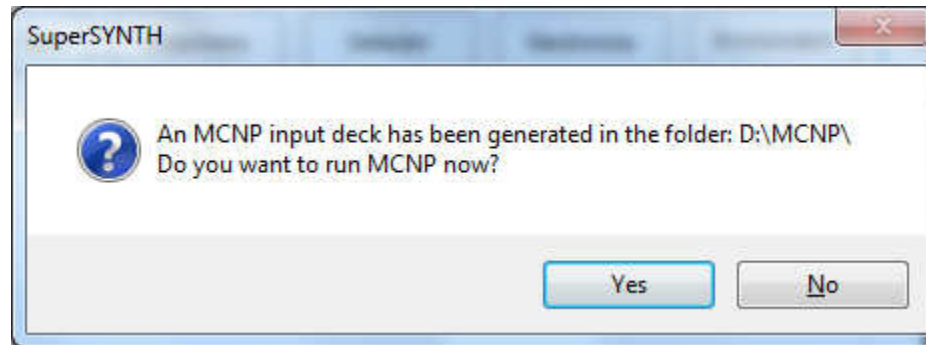
3072 (keV)

Return

# Counting Environment



# Generated Input Deck



- All of the surfaces in the generated input deck are on translation cards so you can easily pull one or more components out of the model and reuse them in another project!

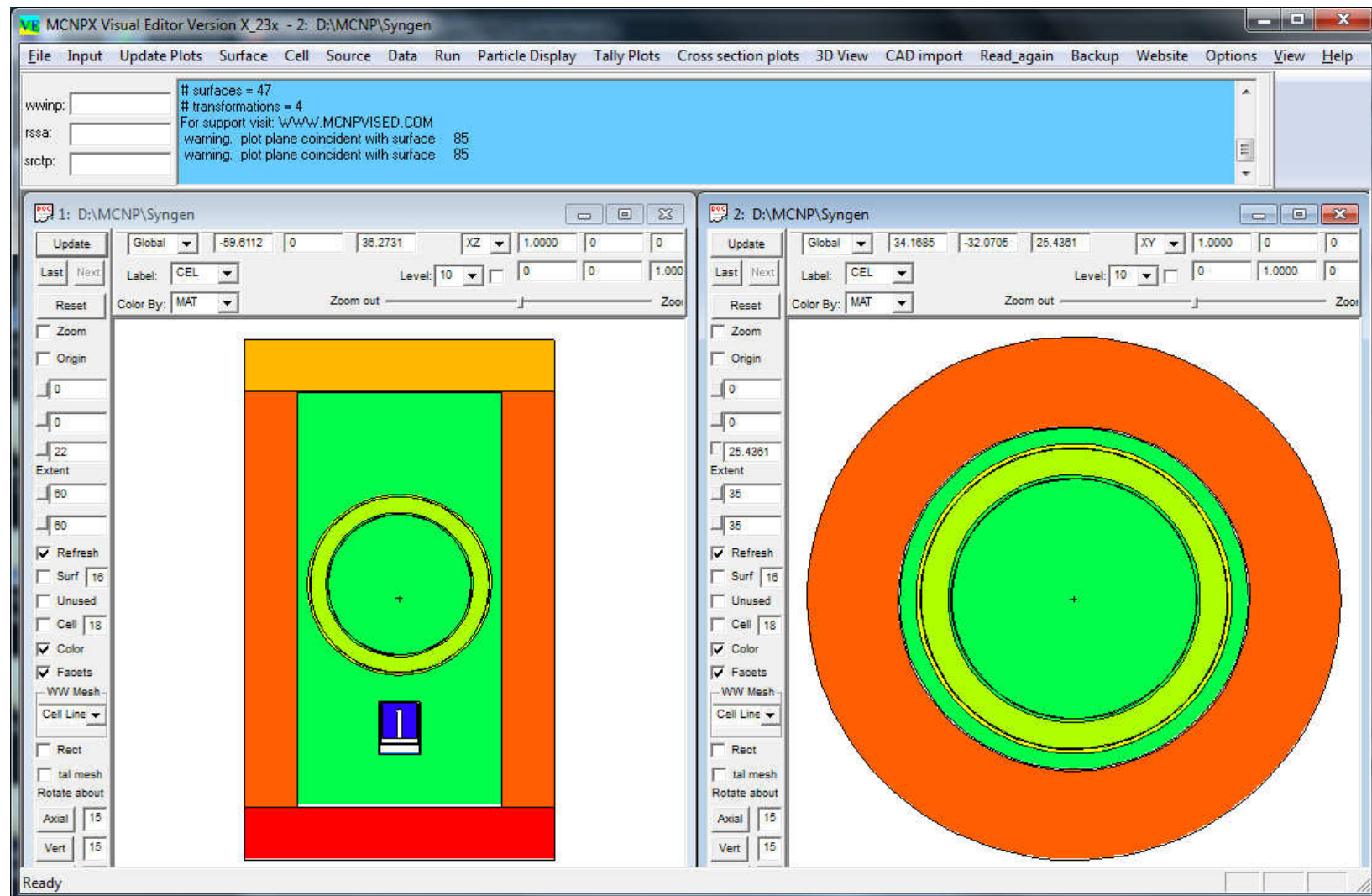
```

. . .
c
c Outer Shield
c
  906  4  cz      32.768 $ Outer Bounding cylinder
  907  4  pz      49.966 $ Outer Bounding top Surface
  908  4  pz     -45.570 $ Outer Bounding bottom Surface
c
c REQUIRED blank line to separate Surface cards from Data cards

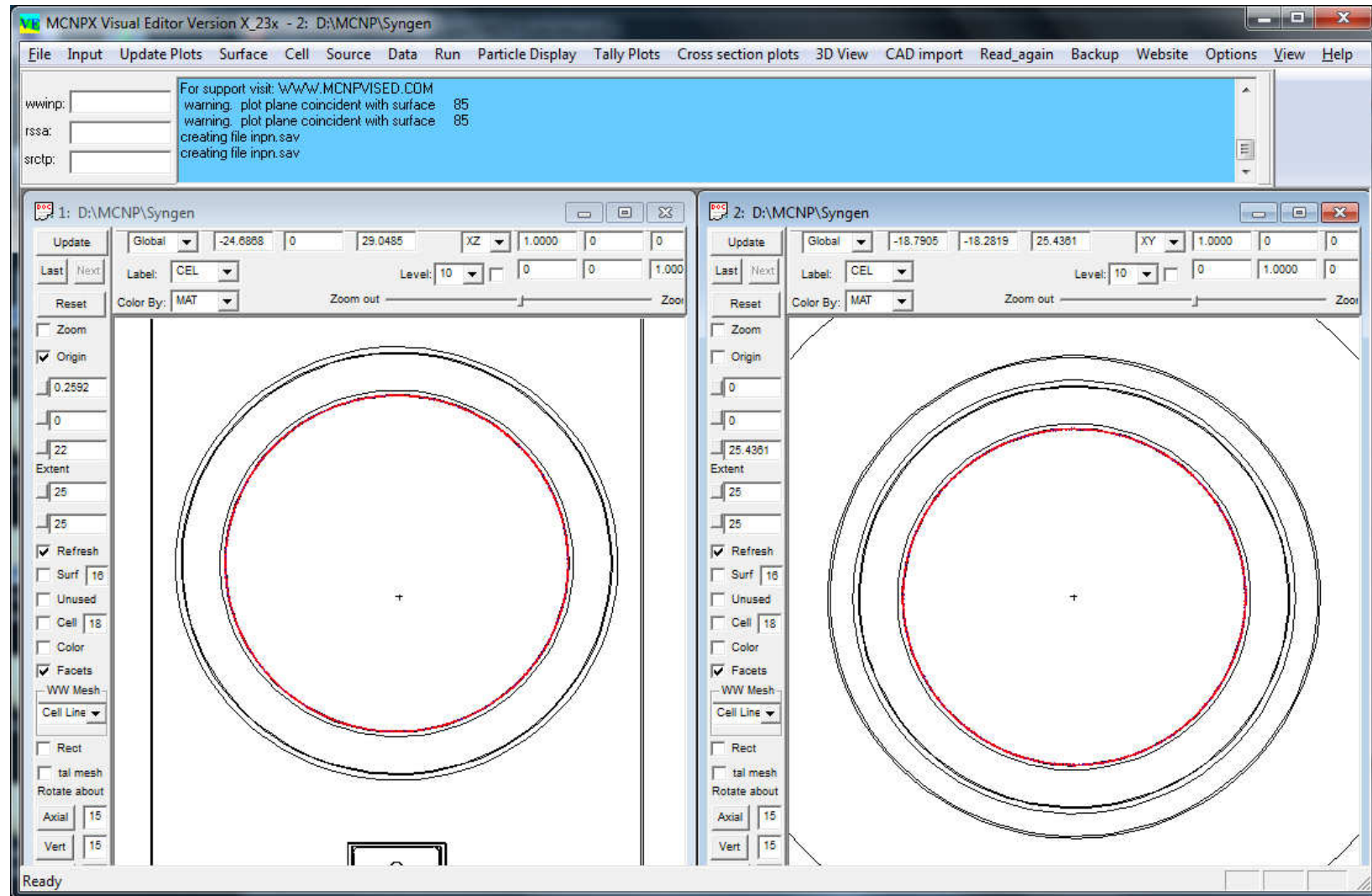
c ***** Data cards *****
c
c
c Surface Translation Cards
c
c Translations to move detector and other elements to appropriate location and
c orientation. The detector, as defined above, is pointed in the +z direction.
c The translation cards below rotate the detector to be facing along different
c axes.
c
c      x  y  z   xx'  yx'  zx'   xy'  yy'  zy'   xz'  yz'  zz'
c *tr1  0  0 -8    0   90   90    90  180   90           $ rotate +z to -z
c *tr1 -4  0  0    90   90    0    90   0   90           $ rotate +z to -x
c *tr1  4  0  0    90    0   90    90  90    0           $ rotate +z to +x
c *tr1  0 -4  0     0   90   90    90  90    0           $ rotate +z to -y
c *tr1  0  4  0    90   90    0     0  90   90           $ rotate +z to +y
c *tr1  0  0  4           $ no rotation, just translation
c
c The following translations are used in this model.
c
Tr1      0.0    0.0    0.0    $ Sensor
Tr2      0.0    0.0    0.0    $ Source
Tr3      0.0    0.0    0.0    $ Absorbers
Tr4      0.0    0.0    0.0    $ Environment
C
. . .

```

# Check the Geometry

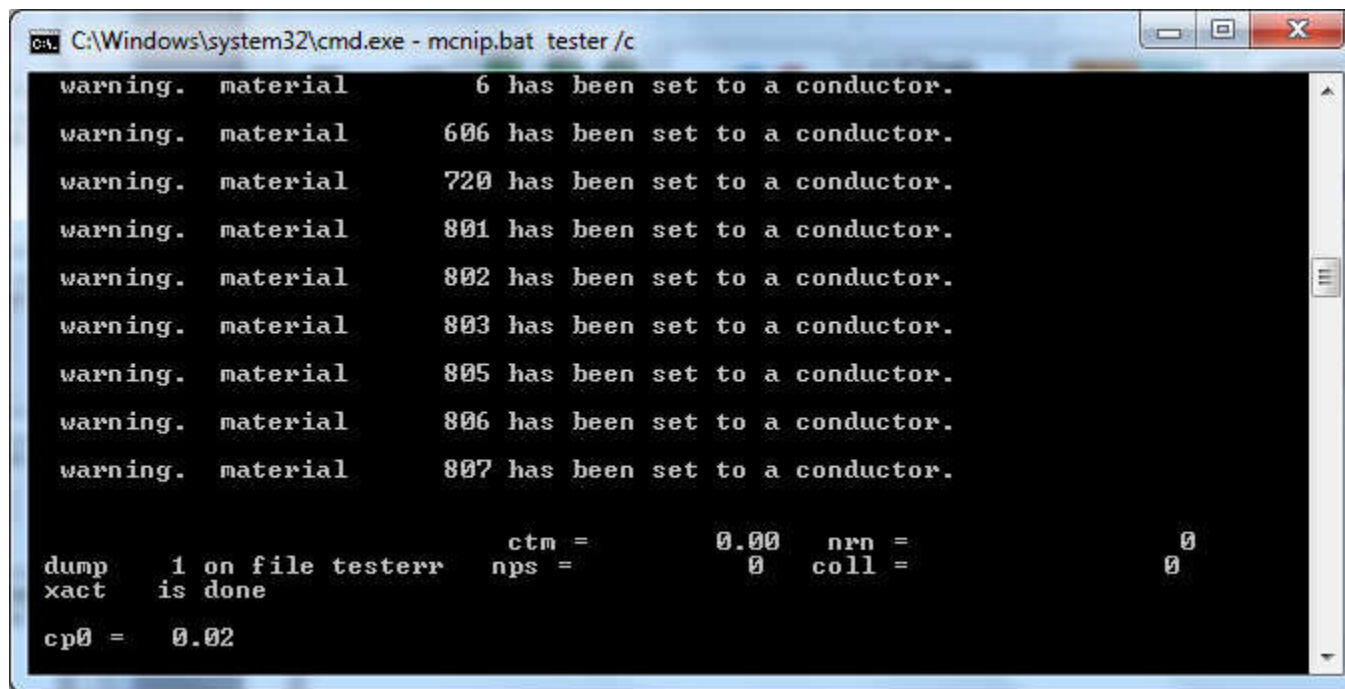


# And the Source Location



# Estimate MCNP Run Time

- Test run with nps 1000000



A screenshot of a Windows command prompt window. The title bar reads "C:\Windows\system32\cmd.exe - mcnp.bat tester /c". The window has a black background with white text. The output shows several warning messages about materials being set to conductors, followed by a summary of the run parameters.

```
C:\Windows\system32\cmd.exe - mcnp.bat tester /c

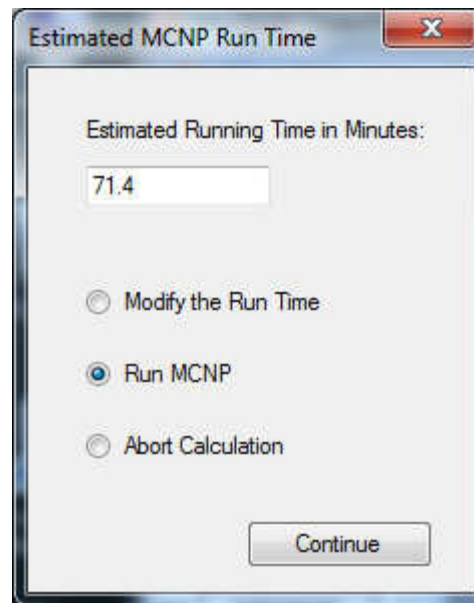
warning. material      6 has been set to a conductor.
warning. material    606 has been set to a conductor.
warning. material    720 has been set to a conductor.
warning. material    801 has been set to a conductor.
warning. material    802 has been set to a conductor.
warning. material    803 has been set to a conductor.
warning. material    805 has been set to a conductor.
warning. material    806 has been set to a conductor.
warning. material    807 has been set to a conductor.

dump      1 on file testerr      ctm =      0.00      nrn =      0
xact      is done      nps =      0      coll =      0

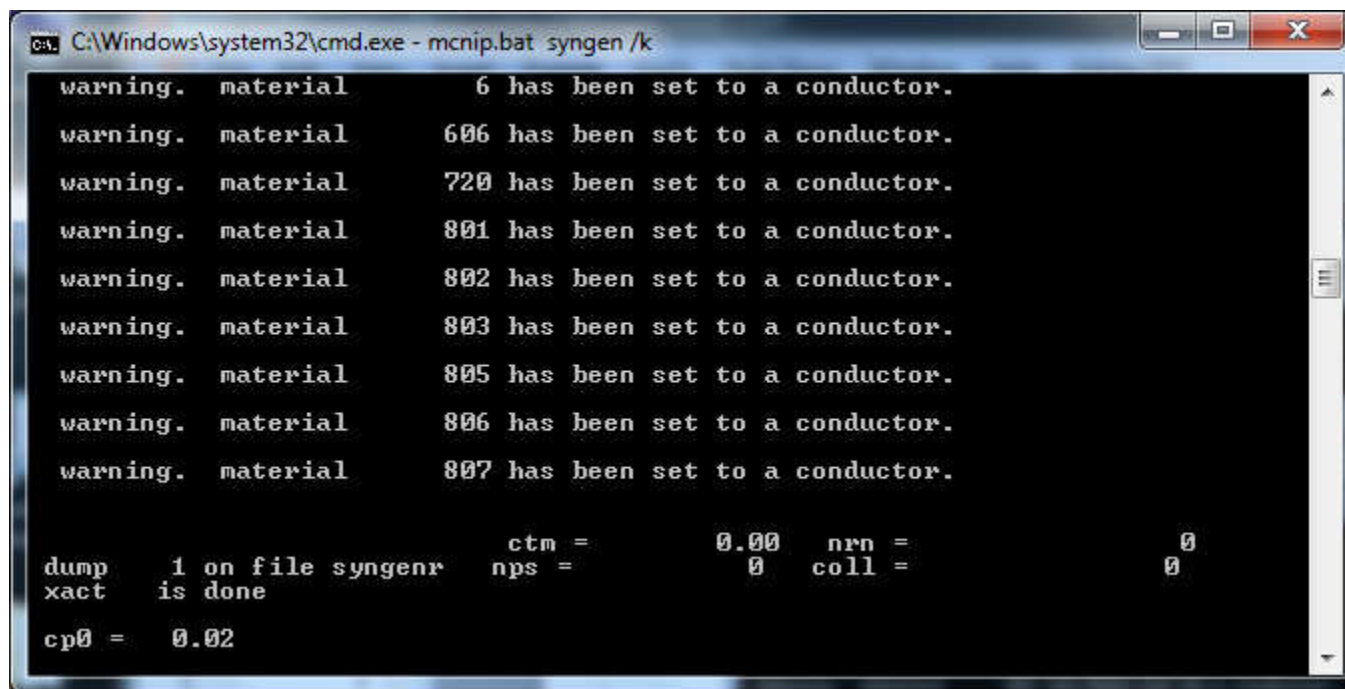
cp0 =      0.02
```

# MCNP Run Options

- Calculate the full run time and display some options



# Running the Selected Option



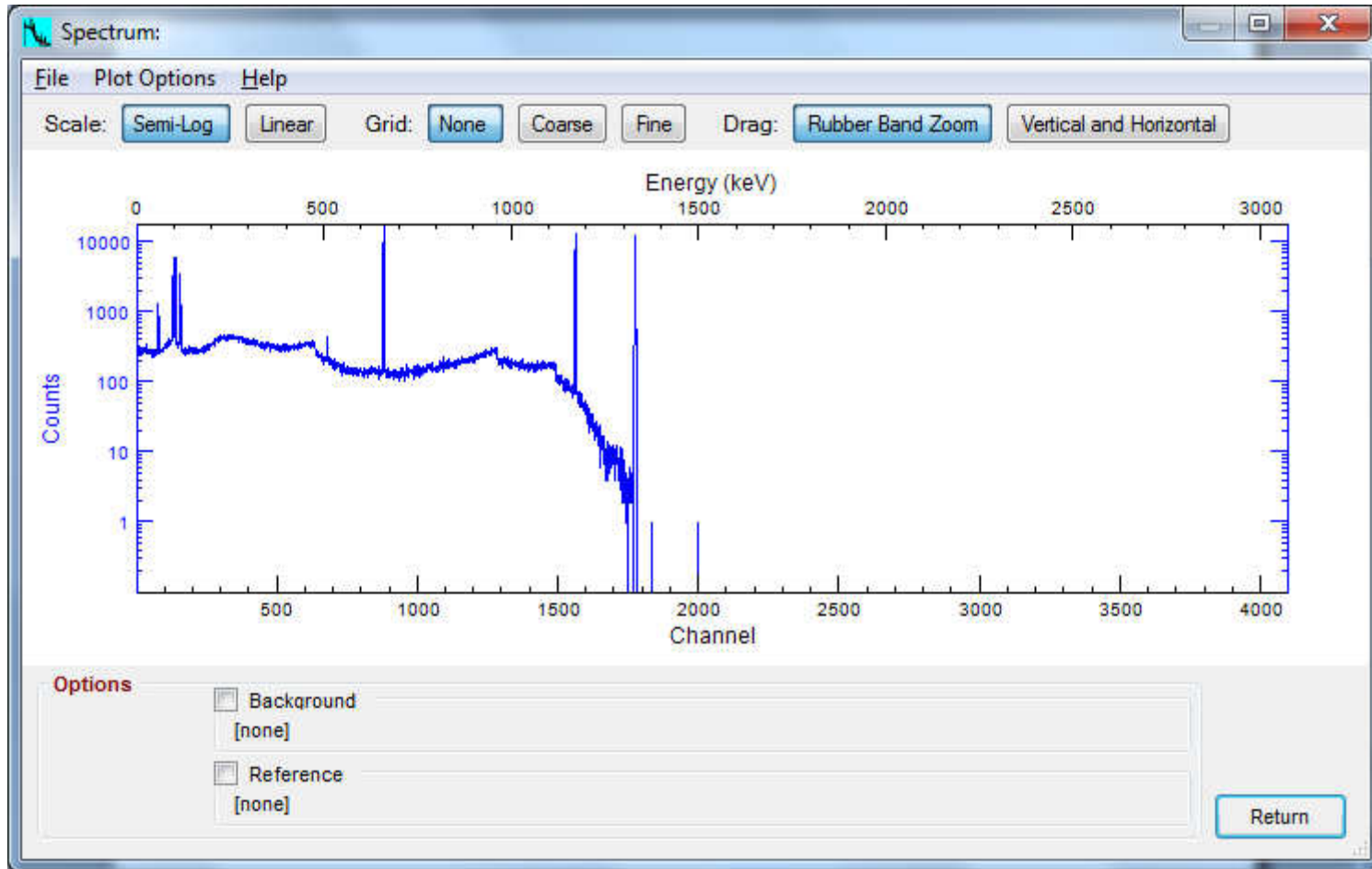
A screenshot of a Windows command prompt window. The title bar reads "C:\Windows\system32\cmd.exe - mcnip.bat syngen /k". The window has a black background with white text. The output consists of nine lines of warnings, each stating that a specific material has been set to a conductor. At the bottom, there are several lines of status information including "dump 1 on file syngenr", "xact is done", and various numerical values for "ctm", "nps", "nrn", "coll", and "cp0".

```
C:\Windows\system32\cmd.exe - mcnip.bat syngen /k

warning. material      6 has been set to a conductor.
warning. material    606 has been set to a conductor.
warning. material    720 has been set to a conductor.
warning. material    801 has been set to a conductor.
warning. material    802 has been set to a conductor.
warning. material    803 has been set to a conductor.
warning. material    805 has been set to a conductor.
warning. material    806 has been set to a conductor.
warning. material    807 has been set to a conductor.

dump 1 on file syngenr      ctm =      0.00      nrn =      0
xact is done              nps =      0      coll =      0
cp0 =      0.02
```

# View the Generated Spectrum



# Break / Questions

# Practical

- Source
  - Point, Volume
- Source Term
  - No decay, Decay
- Absorbers
- Detectors
  - Ge, RCC, Box
- Electronics
- Environment
- Spectrum Options